AUTONOMOUS NETWORK DOCKING NODE

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LONG-TERM GOALS

To integrate REMUS and this underwater docking system into a re-locatable sampling network whose strategies may be altered as data assimilative predicative computer models generate revised descriptions of the local scene and identify arenas of interest and uncertainty.

OBJECTIVES

To develop and demonstrate a reliable and economically practical means of autonomously docking an AUV to an underwater platform in littoral waters for the purpose of data up/download, mission planning, battery recharging, and network status reporting.

Figure 1: Launch of the docking system for testing

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APPROACH

Mechanically, this approach is based on an earlier system called the “flying plug” which was developed by NRaD [1]. Their approach, like this one, utilizes an entry cone, which guides the vehicle into a cylindrical housing, or docking tube, where it is clamped in place and protected from the environment. This method offers distinct advantages in that the entry cone passively guides the vehicle into its protective storage bay while absorbing the impact shock associated with a 1 -1.5 m/s closing rate. The entry cone also provides a large and forgiving volume of acceptance without impacting vehicle design. These advantages are important for operations which will be conducted in littoral waters where wave induced surge forces, suspended sediments, and bio-fouling present real impediments to success. Beyond these mechanical similarities, our approach diverges from the NRaD system.

Acoustically, the dock provides its location to the free swimming REMUS vehicle via a transponder which is mounted on it. Each REMUS vehicle is equipped with a DSP based ultra short baseline navigation system know as RATS [2]. This system provides absolute range and relative bearing to the dock’s transponder. This approach assumes that the vehicle has apriori knowledge of the dock’s depth and orientation (heading). This requirement could be eliminated by integrating an acoustic telemetry system into the vehicle and the dock. Conceptually, the vehicle navigates itself to within 2 km of the dock, and then begins to interrogate the dock’s transponder system. After computing its location relative to the dock, the vehicle navigates onto its final approach path and swims into the dock’s entrance by converging to a virtual point which is an offset of the transponder location and is near the center of the cone.

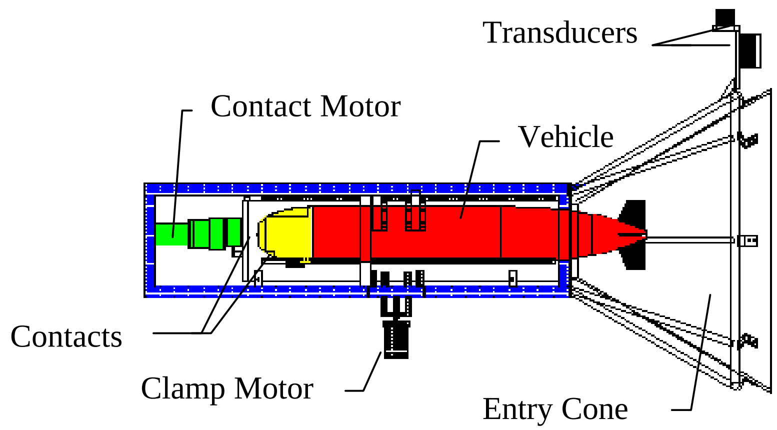

Figure 2: REMUS Dock Block Diagram

The major electrical components of the dock include:

1. A PC-104 based computer for monitoring subsystems, controlling motors, and providing a serial interface to the outside world;
2. Clamp and contact motors which are used to lock the vehicle into the docking tube and to move the electrical contact probe required for bi-directional communication and battery recharging into position with their mates which are located on the nose of the vehicle;
3. A sensor sub system which includes a compass, a vehicle “within the dock” position sensor, and leak, ground fault, and current sensors;
4. An acoustic navigation system which includes a RATS identical to the one used in the vehicle;

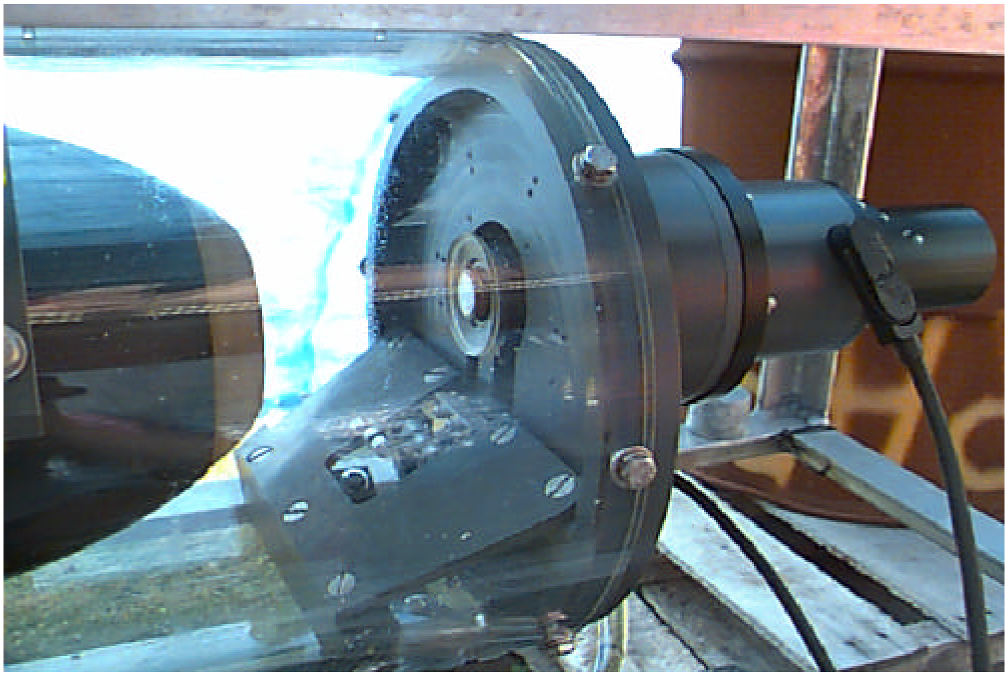

Figure 3 Contacts used in docking system

5. Electrical circuitry required to recharge the vehicle’s batteries and to provide bi-directional communication with the vehicle.

Once the vehicle has entered the docking tube, a sequence of events is initiated by a position sensor which is used to detect and track the position of the vehicle while it is in the docking tube. When the vehicle reaches its home position, as detected by this sensor, the system computer initiates the clamping cycle, which locks the vehicle into place in the tube. Once the vehicle is locked in place, a second motor moves the dock’s electrical contacts into position with a matching set on the nose of the vehicle, (see Figure 3). Both power for recharging the vehicles batteries and telemetry share an insulated pin on the nose cone of the vehicle, with the return path through an un-insulated contact which is exposed to seawater. As may be seen in Figure 3, a soft polyurethane suction cup forms a seal as it is pressed against the nose of the vehicle. A number of features have been incorporated into this design to prevent electrolytic corrosion and to deal with bio-fouling.

Battery recharging circuitry, on REMUS’s mother board, supports “smart” battery technology. This design will permit the use of most practical chemistries in the future. The “smart” battery interface is an industry standard communications interface which allows the REMUS CPU to monitor and control the charge and discharge characteristics of each individual battery pack. The use of this commercial standard will provide a more predictable battery capacity and minimize the out-gassing of hydrogen. The reliability of the system should be increase over that possible with a simple current limited charging system.

Telemetry between the dock and the vehicle is provided by commercial short haul modems that modulate the data to a 10-300 kHz band. The selected modems provide a full duplex link at 56 kbaud. Power/telemetry separation filters have been placed in both the vehicle and the dock. These modifications, as well as the battery recharging circuitry, required improvements to the REMUS mother board. They are required to support battery charging without opening the housing.

WORK COMPLETED

The following tasks have been completed:

1. Researched the existing technology base in underwater docking systems and exchanged information and ideas with other projects;
2. Developed a simple two dimensional hydrodynamic simulator in MATLAB to model the performance of the vehicle in various cross currents as it enters the dock;
3. Performed harbor trials in Woods Hole Harbor, to test navigation concepts and to establish the minimum diameter of the dock's entry cone;
4. Designed, fabricated, the mechanical portions of the dock and tested them in Woods Hole harbor;
5. Designed and fabricated the dock's electrical and acoustic interface (Battery charging and bi-directional communication are being added to this system.);
6. Performed a detailed study of ways of preventing hydrogen buildup in the AUV when recharging the vehicle's batteries with the housing closed.
7. Fabricated the dock's seafloor pedestal which anchors it to the seafloor, in open coastal waters such as those found at the LEO-15 site.

RESULTS

The following results were obtained:

1. Demonstrated that a REMUS vehicle can back out of the dock, swim away, relocate the dock, and swim into the entry cone in a 0.5 m/s cross current.
2. Demonstrated that the vehicles presence in the dock can be detected and tracked with an inductive tracking sensor;
3. Demonstrated that we can clamp the vehicle into the docking tube;
4. Established that the docking cone is a reasonable approach for operations which will be conducted in littoral waters, and that an inductive charging system appears to be too heavy and large for a vehicle as small as REMUS;
5. Demonstrated that the contact system for communication and battery recharge described above will isolate the contact reliably and repeatably in water;
6. Demonstrated that the contact system can compensate for expected translational and rotational offsets that will occur over repeated docking cycles;
7. Determined that the navigation system can detect the dock at 2 km in shallow coastal waters 8-15 m and that the vehicle can close well within the one meter wide entry cone. It was determined that the acoustic system has a resolution of approximately 0.5 degrees and an accuracy of 2 degrees.

IMPACT/APPLICATIONS

The development of an autonomous docking station and a REMUS vehicle that can dock to it will allow the vehicle to be part of an autonomous ocean sampling network. In addition, this capability may be used to support the needs of various Naval Special Warfare programs, the Naval Oceanographic Office, as well as those of other branches of the Navy.
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TRANSITIONS

The technology developed under this program has already been transitioned to the Applied Physics Laboratory at the University of Washington (APL-UW) and to the Naval Undersea Warfare Center (NUWC) in Newport. The three vehicles delivered to NUWC and the one vehicle delivered to APL-UW have new mother boards which include the circuitry required for autonomous docking (battery recharging and bi-directional communication). This technology will also be used in a multi-scale model directed experiment which will be conducted at the LEO-15 site during July of 1998. This program is funded under the National Ocean Partnership Program, and utilizes autonomous underwater vehicles as well as other remote sensing techniques in an interactive (computer model driven/real time data assimilation) experiment.

RELATED PROJECTS

Related projects include:

1. Multi-scale model-directed sampling with autonomous systems at a National Littoral Laboratory, A National Ocean Partnership Program, managed by ONR and funded through subcontract agreement 894 with Rutgers the State University of New Jersey. This program will use REMUS and its docking station in a number of model directed experiments which will study seasonal up-welling off the coast of New Jersey;
2. Navy Special Warfare Support with REMUS vehicles; ONR N00014-98-10135; the program uses REMUS vehicles to support Naval Special Warefare missions involving very shallow water mine counter measures;
3. Hydrography with affordable AUV systems; ONR N00014-96-5021, The programs goals are to demonstrate the capability of current generation AUVs to perform hydrodynamic surveys;
4. MURI Labrador Sea program with Odyssey
5. National Ocean Partnership Program awarded to MIT/Havard

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